REPORT DOCUMENTATION PAGE

Form Approved OMB NO. 0704-0188

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (From - To)
	Technical Report	-

4. TITLE AND SUBTITLE
Collaboration with NIST to provide ErAs:GaAs Epitaxial Layers

5a. CONTRACT NUMBER
W911NF-12-1-0496

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
611102

6. AUTHORS
Elliott Brown, Matthieu Martin, Jack Owsley

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAMES AND ADDRESSES
Wright State University
Wright State University
3640 Colonel Glenn Highway
Dayton, OH 45435 -0001

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Research Office
P.O. Box 12211
Research Triangle Park, NC 27709-2211

10. SPONSOR/MONITOR'S ACRONYM(S)
ARO

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
62602-EL.6

12. DISTRIBUTION AVAILIBILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
The views, opinions and/or findings contained in this report are those of the author(s) and should not contrued as an official Department of the Army position, policy or decision, unless so designated by other documentation.

14. ABSTRACT
A key aspect of our project is obtaining new ErAs:GaAs epitaxial layers for the development of useful THz extrinsic-photoconductive (PC) devices. To accomplish this a CRADA and purchase order were established with Dr. Rich Mirin at NIST in Boulder, CO. Dr. Mirin did his Ph.D. in the same molecular-beam epitaxy (MBE) group at UC Santa Barbara that developed the useful ErAs:GaAs epitaxial layers in the late 1990s. During the reporting period, Dr. Mirin delivered to Dr. Brown's group at Wright State four ErAs:GaAs epitaxial layers on

15. SUBJECT TERMS
Molecular Beam Epitaxy; Erbium Doping; Ultrafast Photocarrier Lifetime

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	15. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Elliott Brown
UU	UU	UU	UU		19b. TELEPHONE NUMBER: 937-775-4903

Report Title

Collaboration with NIST to provide ErAs:GaAs Epitaxial Layers

ABSTRACT

A key aspect of our project is obtaining new ErAs:GaAs epitaxial layers for the development of useful THz extrinsic-photoconductive (PC) devices. To accomplish this a CRADA and purchase order were established with Dr. Rich Mirin at NIST in Boulder, CO. Dr. Mirin did his Ph.D. in the same molecular-beam epitaxy (MBE) group at UC Santa Barbara that developed the useful ErAs:GaAs epitaxial layers in the late 1990s. During the reporting period, Dr. Mirin delivered to Dr. Brown's group at Wright State four ErAs:GaAs epitaxial layers on 3-inch SI-GaAs substrates. The first two were morphologically rough and not amenable to optical testing. The second two were much better and are described in the associated Technical Report. Wright State carried out three important characterizations of these two samples: (1) sheet resistance measurements by the four-point-probe method, (2) VIS-IR measurements of the transmittance around the GaAs band-gap, and (3) ultrafast pump-probe phototransmission measurements with a 1550-nm (EDFA) mode-locked laser. All three provided interesting results, especially the ultrafast pump-probe characterizations which demonstrated ~0.33 ps FWHM for each of the two promising samples. The near-term plan is to start fabricating PC switches and photomixers with these samples during October 2013 in the new WSU cleanroom.

Characterization of ErAs-GaAs Epitaxial Layers from NIST
(grown by Dr. Rich Mirin)

M. Martin, J. Owsley, and E.R. Brown
Wright State University
Depts. of Physics and Electrical Engineering

3 Sept. 2013

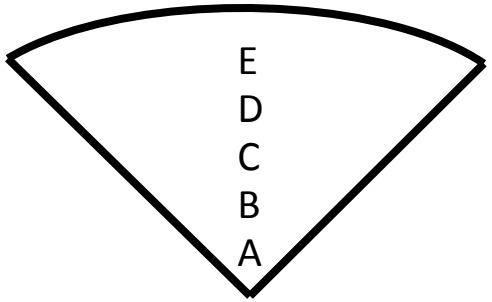
Four-Point Probe Resistance Measurements

Calculated Sheet Resistivities at Target Locations (A-E) for Samples ASP011 and ASP013

- ASP011
  - A= 4.6 Ω-cm
  - B=15.5 Ω-cm
  - C= 18.21 Ω-cm
  - D= 181 Ω-cm
  - E= 15.402 *10^3 Ω-cm
- ASP013
  - A= 2.44 Ω-cm
  - B= 2.178 Ω-cm
  - C= 15.76 Ω-cm
  - D= 18.12 Ω-cm
  - E= 160 Ω-cm

Assumption: t = 0.0002 cm

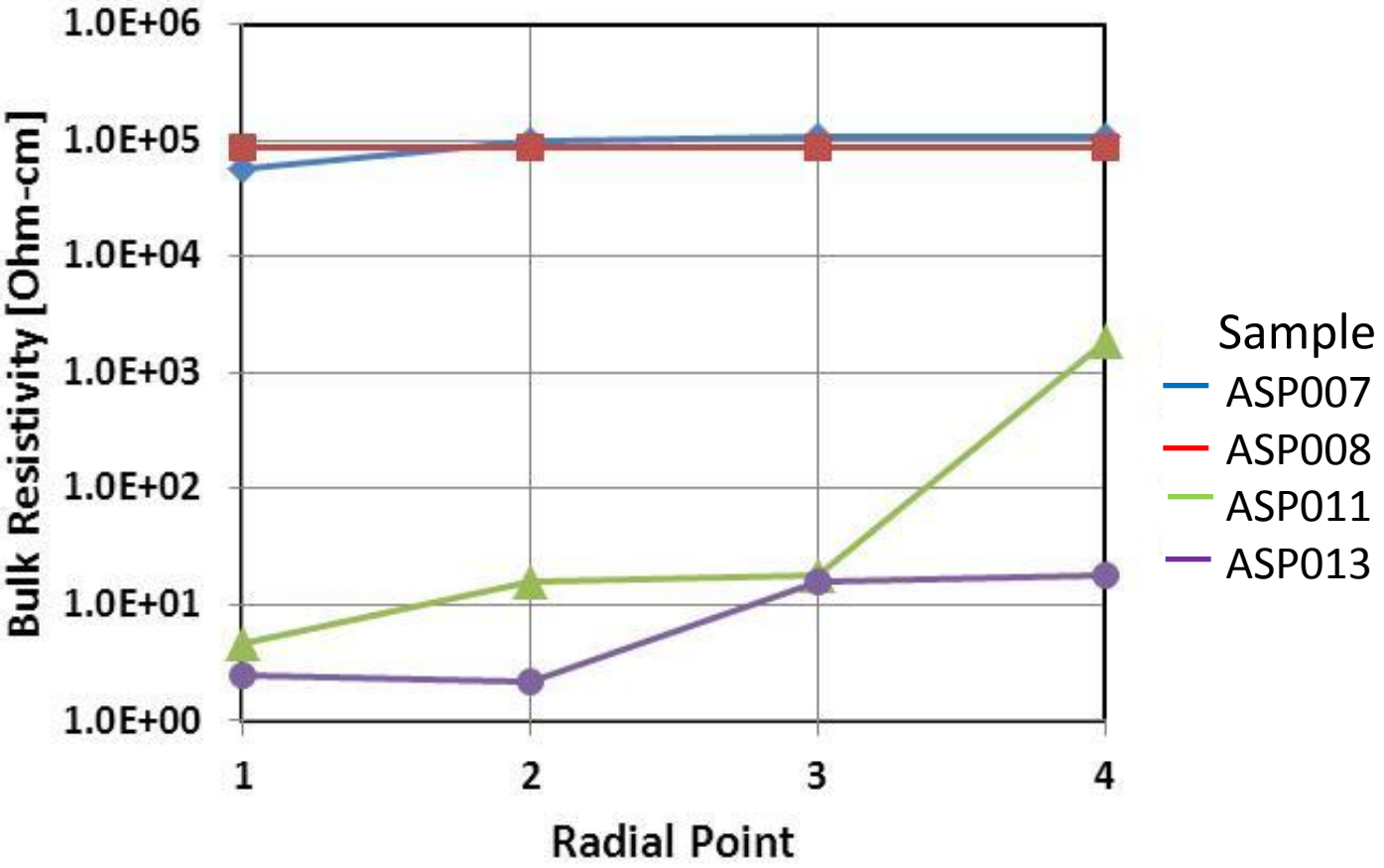
Sample Targets and Sheet Resistivity Equation



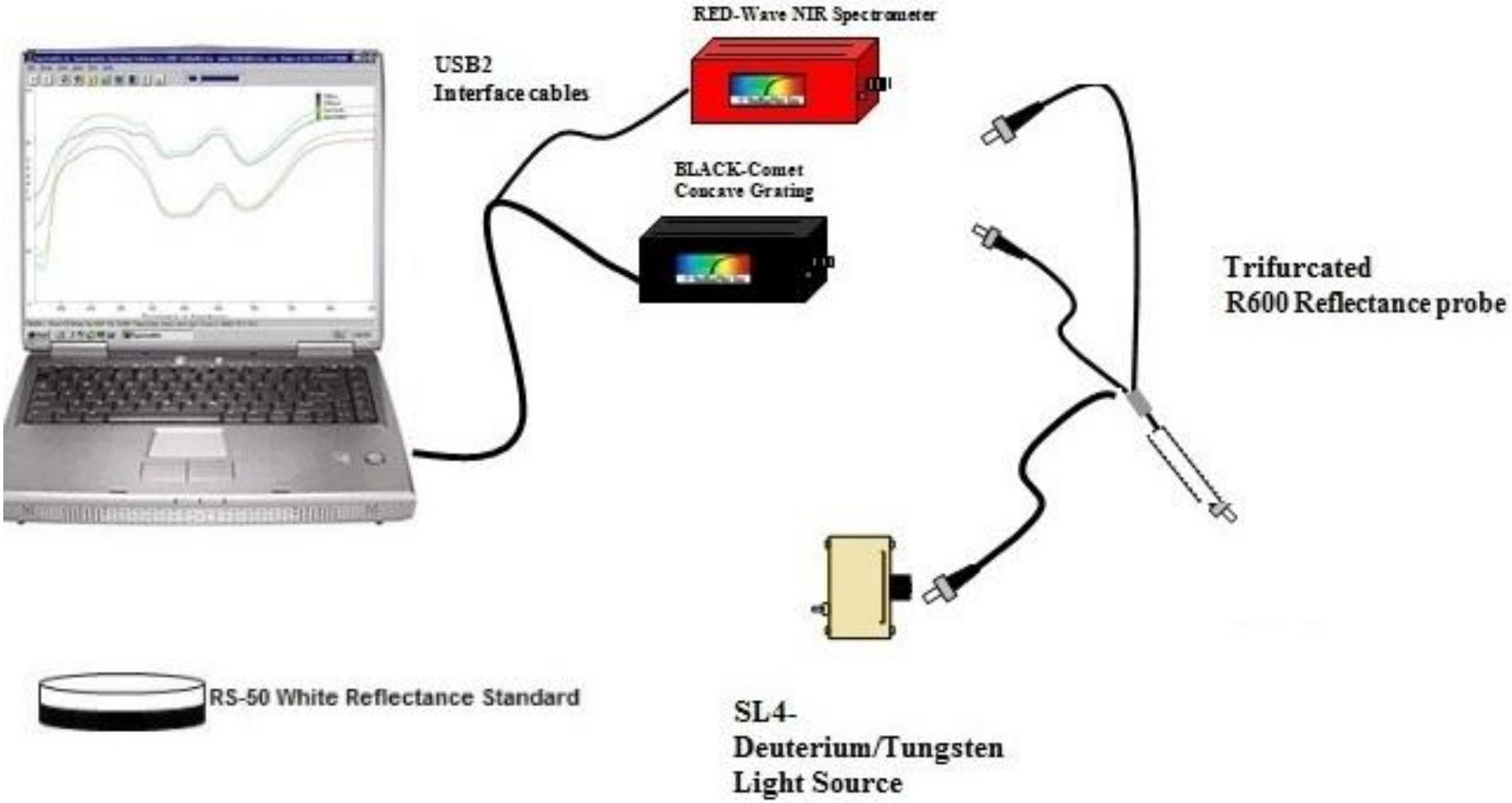
$$\rho_{sheet} = 4.53 * t * (\frac{V}{I})$$

Note: Bulk resistivity of semi-insulating GaAs was measured to be 1.17x10^8 Ω-cm

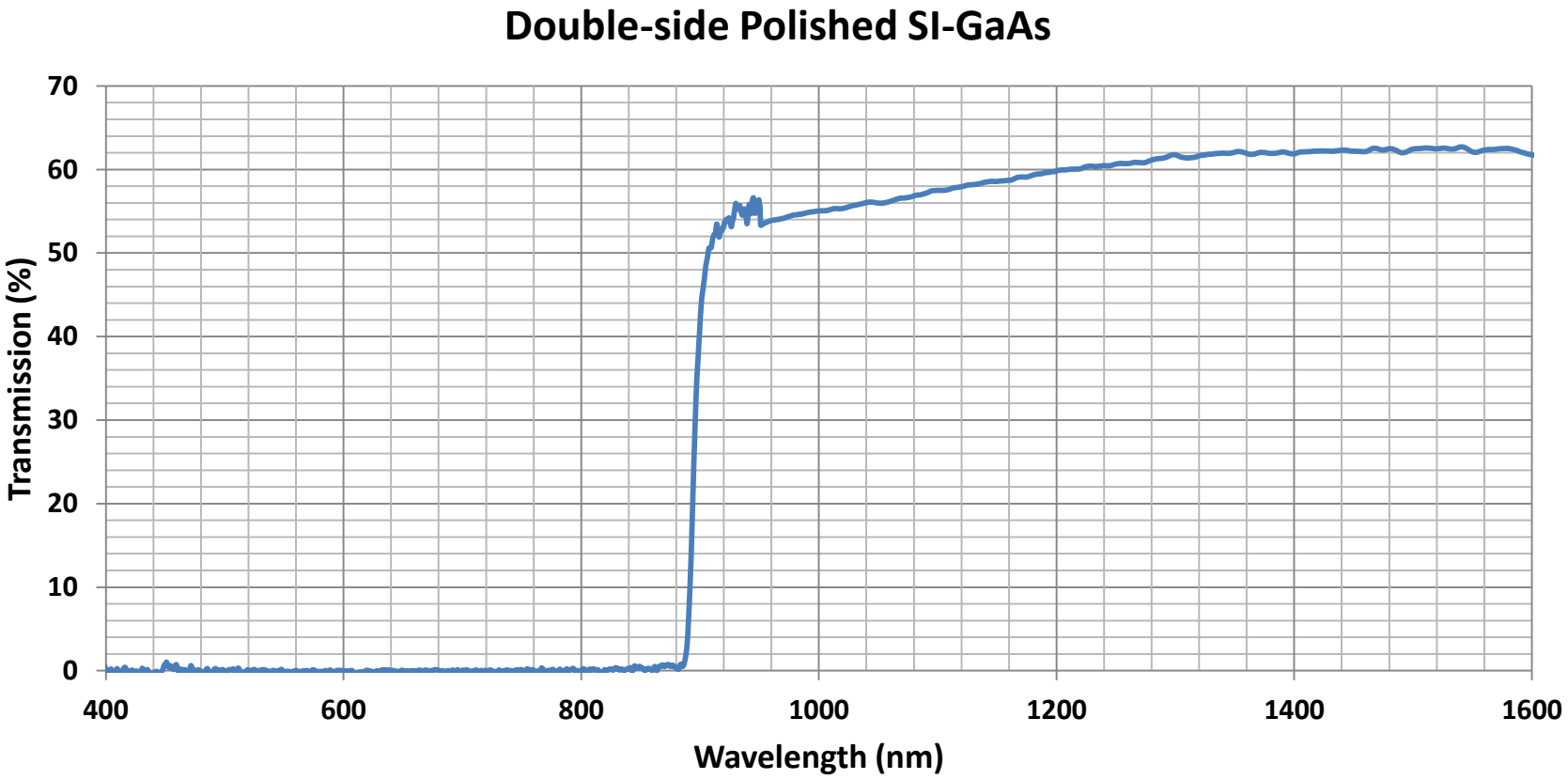
Four-Point Probe Resistance Measurements



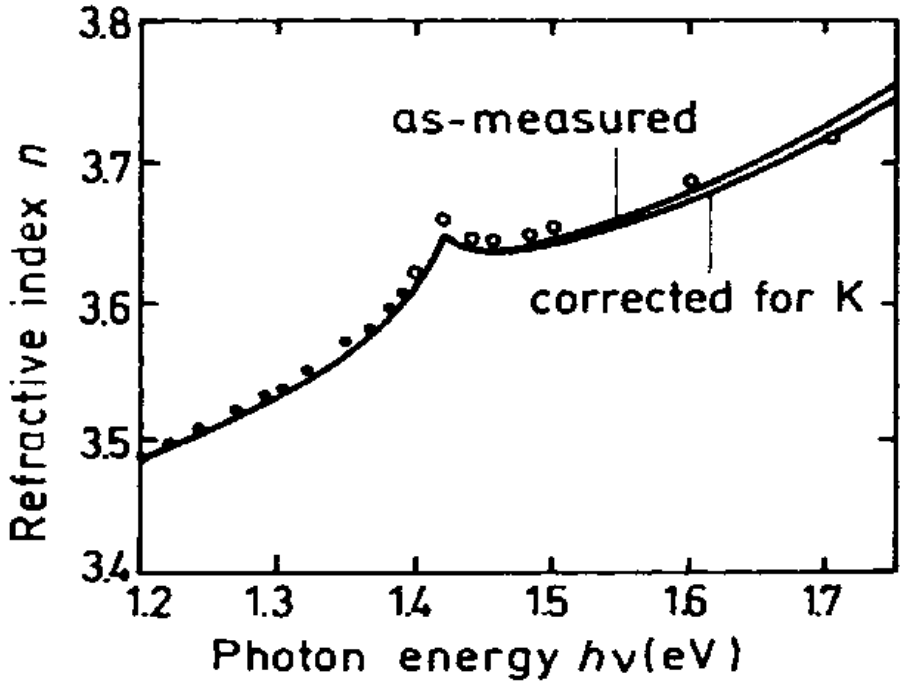
Below-Band-Gap Transmittance Measurements



Below-Band-Gap Transmittance Measurements



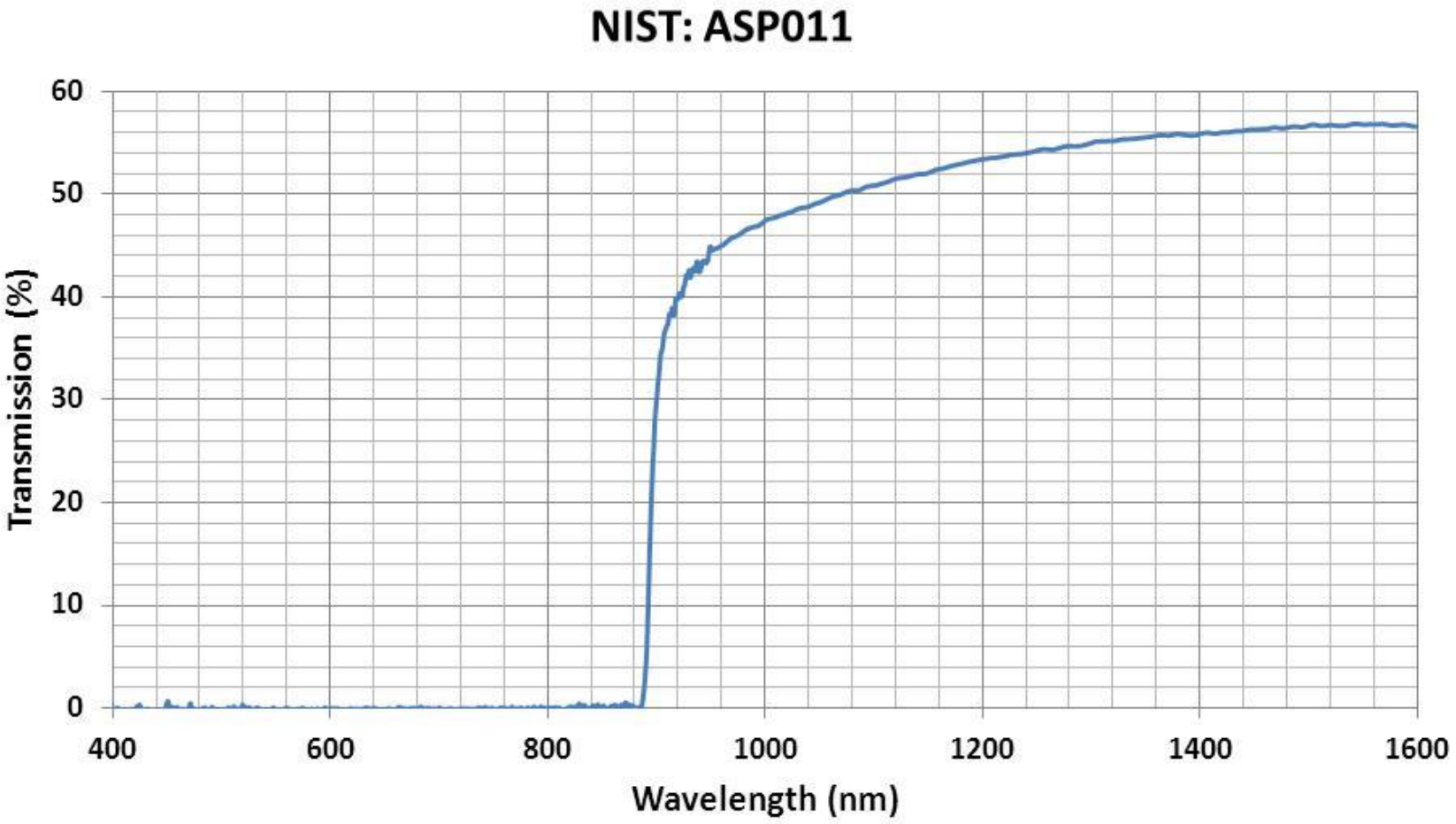
GaAs Refractive Index and Expected Substrate Transmittance



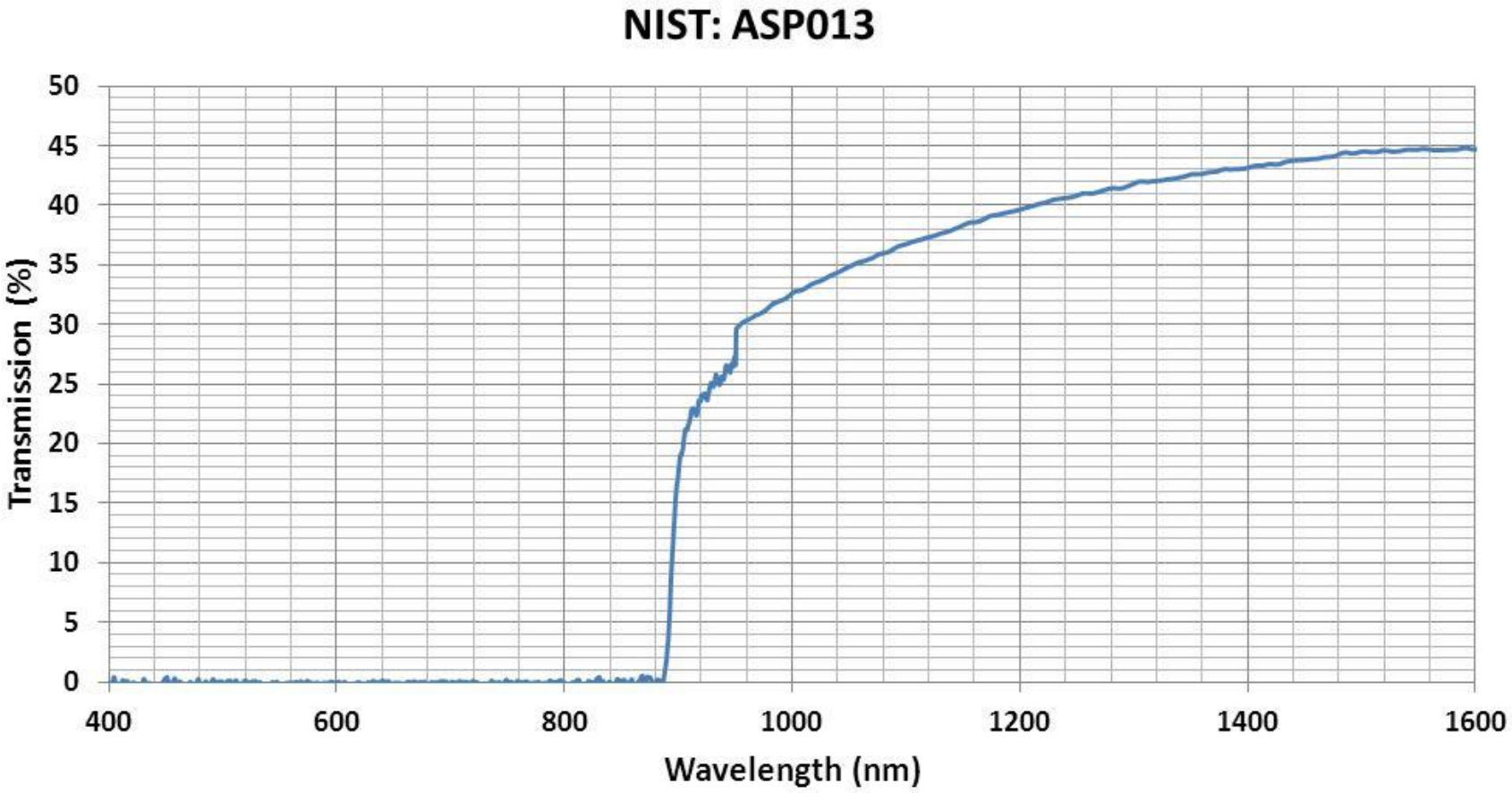
photon energy [eV]	1.2
frequency [Hz]	2.90E+14
wavelength [m]	1.03E-06
refractive index [from Blakemore]	3.48
reflectance	0.31
single-interface transmittance	0.69
two-surface transmittance	0.48

Blakemore, J. S., *J. Appl. Phys.* **53**, 10 (1982) R123-R181.

Below-Band-Gap Transmittance Measurements

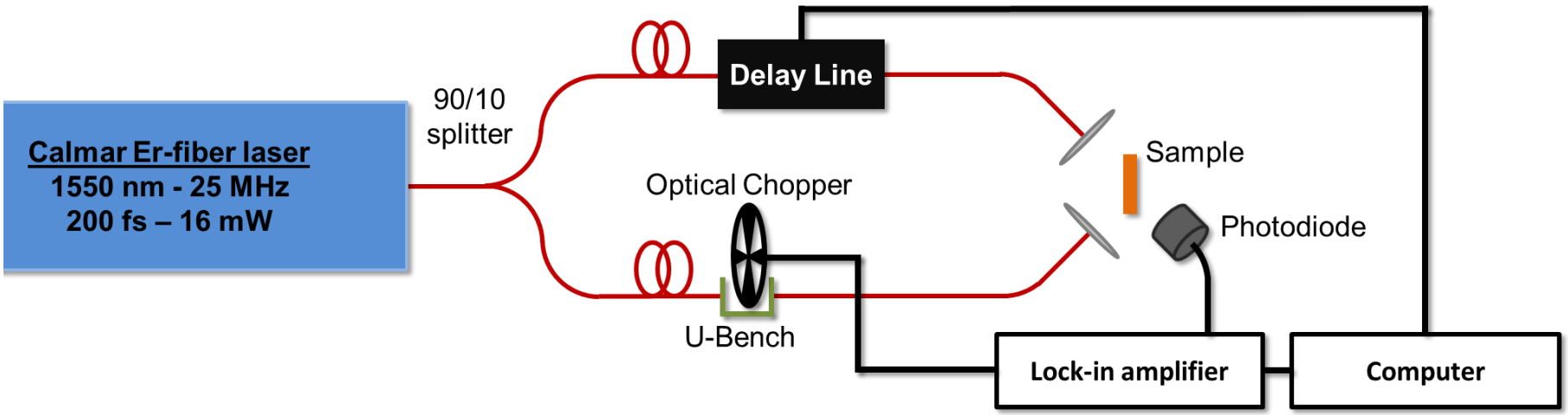


Below-Band-Gap Transmittance Measurements

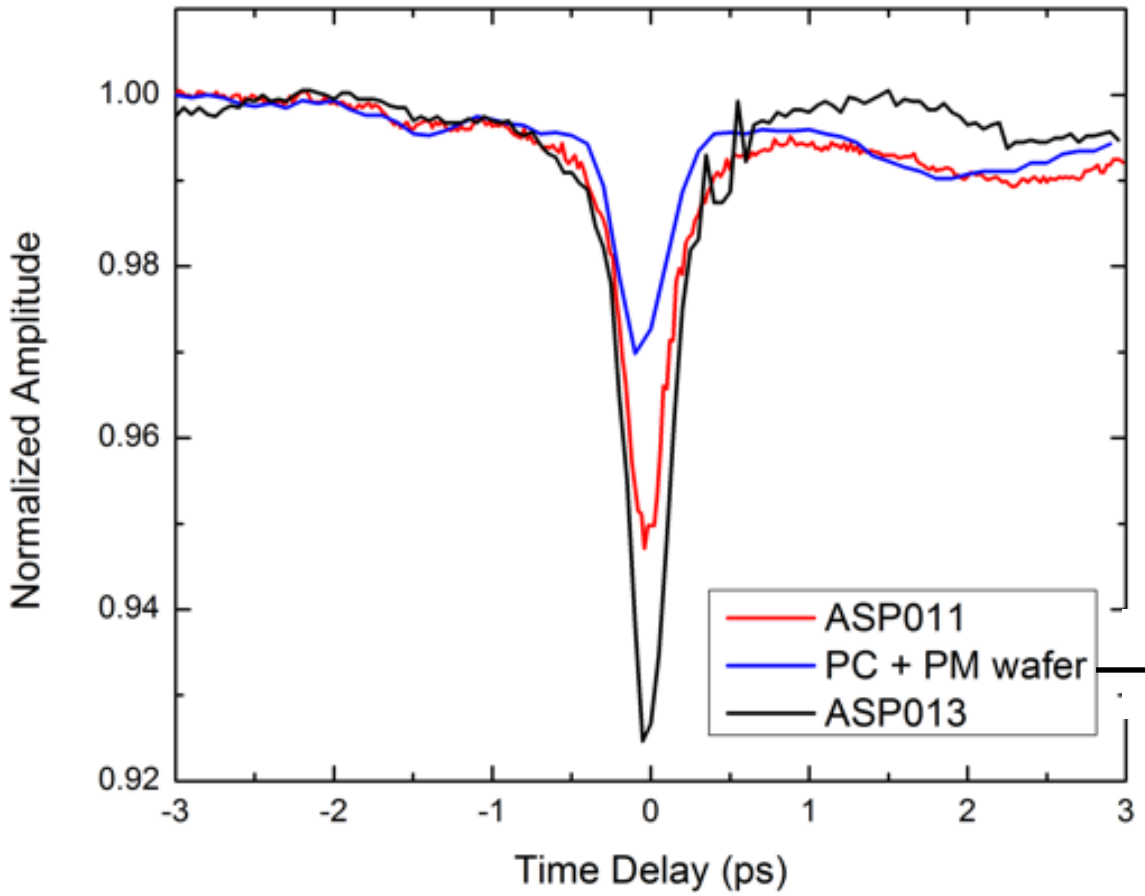


Comment: greater insertion loss of ASP013 compared to ASP011 below band-edge consistent with more surface roughness of ASP013. Discontinuity at ~950 nm caused by splicing of two insrtumental data

1550-nm Ultrafast Pump-Probe Photo-Transmission Set-Up



1550-nm Ultrafast Pump Probe Results



(Control Sample: 1% ErAs-GaAs wafer leftover from UCSB)

Sample	Width (ps)	Amplitude	Amplitude compared to ErAs:GaAs Control
Control	0.36	0.025445	1.00
ASP011	0.33	0.04417	1.74
ASP013	0.32	0.07165	2.82